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THE MONIST

INFINITY OF THE UNIVERSE.[1]

EVER since the earliest period of Greek philosophy two distinctly different theories of the extension of the universe have been propounded. According to one of them, which no doubt originated in the naive world-conception of primitive man, the universe is finite and the earth or sometimes the sun occupies its central position. The Pythagorean school (in the sixth century B. C.) placed a hypothetical "central fire" in this point, around which the heavenly bodies were uniformly arranged in all directions, and according to this school therefore the universe was globe-shaped. Also in the Aristotelian and Ptolemaic systems the earth, supposed to be the center, was surrounded by several spheres, the outermost of which was the Firmament, the seat of the fixed stars. Aristotle's theory received the sanction of the church of the middle ages.

In modern times it is assumed by many astronomers that the universe is finite and surrounded by an infinite empty space into which the sun and the stars radiate an energy forever to remain lost. Frequently also the idea is voiced that our sun occupies a position near the center of such a finite universe. We might for instance recall the passionate discussion that for some years followed similar utterances by the renowned English biologist, Wallace. The world is then frequently identified with the galactic star-system.

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[1] Translated from the German by J. E. Fries.

On deeper reflection, however, arose the by no means far-fetched idea of an infinite universe. That space is unlimited is evidently conceded by everybody. Very remote parts of the universe we cannot observe. But it is an axiom that when something is beyond the reach of our senses we must assume it qualitatively to be similar to that within our reach. Our knowledge of the outside world we have derived through our sense-perception and something qualitatively different from our experience we cannot even imagine. It was a quite natural thought, therefore, that infinite space would contain stellar bodies scattered throughout its invisible ranges in a way if not in number, like that in its visible parts.

Anaximander (611-547 B. C.) expressed the theory of an infinite number of heavenly bodies which according to him had evolved from primitive chaos. The somewhat later Demokritos, the greatest nature philosopher of antiquity, taught that the Milky Way consisted of a vast number of stars similar to our sun. The heavenly bodies were infinite in number and subject to gradual changes involving decay and rebirth.

This conception, so strikingly coinciding with our own, is not essentially different from the one later expressed by Giordano Bruno and Kant. According to Bruno, the fixed stars are suns like our own surrounded by inhabited planets. A similar view was expressed with immunity about one hundred years earlier by Cardinal Nicolaus Cusanus. The stellar bodies float in the infinite transparent ether-sea. This theory was further developed by Descartes and was accepted by educated minds up to Newton.

Kant speaks at length—at somewhat too great length—of the qualities belonging to inhabitants of other worlds. He assumed, as is well known, that the sun and likewise other stars develop from a chaos, gradually turn luminous and "burn to ashes." They will, however, awake to new life. "When we endeavor to trace this cosmic Phenix through infinities of time and space and find it consuming itself by fire only in order to arise rejuvenated from the ashes, then the soul, contemplating all these things, is truly inspired with awe." According to this system, the parts of the universe near to us are not essentially different from other interstellar spaces.

A special development of this theory has been given by Swedenborg and Lambert. The sun with its planets and their moons form one system, the solar system. Several solar systems combine in a certain orderly way into a system of higher (second) order to which our solar system stands in a relation somewhat like that of Jupiter with its moons to our solar system. This system of second order, including our sun, forms the galaxy. Several galaxies constitute a higher system of third order. Systems of third order are units in a system of fourth order and so on. This conception has quite recently been quantitatively treated by Professor Charlier of Lund. According to him, the systems of second order—the galaxies— are within the system of third order enormously far apart, or more precisely so far that the nearest galaxy outside of our own would have an apparent diameter of less than 0.2 seconds and a maximum luminosity of a star of the 37th magnitude. It would therefore entirely escape our present power of observation. Systems of third order are millions of times still farther apart, and so on, according to Professor Charlier, and immense spaces void of stars and of exceedingly rapidly increasing extension separate systems of successive orders. This doctrine of an infinite rarity of matter in space no doubt differs radically from the original ideas of the Greek philosophers Anaximander and Demokritos who assumed the density of the stars throughout space about equal to that of our own neighborhood; i. e., of our galaxy.

This theory that our immediate surroundings should differ to such an extraordinary extent (in reality infinitely) from the mean conditions of space, appears to me *a priori* so improbable that a closer examination of the reasons leading up to such a conception seems necessary. These reasons may be summed up in the following way.

Von Olbers pointed out in the year 1826 that if the density of the stars was equal throughout infinite space, then "the entire firmament must be as luminous as the sun." If we consider the stars in a spherical shell of thickness dr and radius r, with our sun in the center, the number of stars in this shell is proportional to its volume $4\pi r^2 dr$. As further the illumination at the center, due to these stars, is proportional directly to the mean luminosity h_r of the shell and inversely to the square of the distance from the shell, the total illumination obtained from these stars is proportional to the expression $h_r d_r$.

If we now circumscribe the sun with a series of such shells bounded by spheres of radii 0, 1, 2, 3, 4, etc., where the unit for instance is 100 light years, the total illumination L becomes: $L = h_1 + h_2 + h_3 + h_4 + \ldots\ldots$

The first terms are not exactly correct, but the later terms are more so the higher their index. This series is not convergent so that L becomes infinite unless the terms decrease more or less in a geometric progression. If we now also assume that the brightness of the stars is independent of their distance from the sun, the series cannot converge. If the mean luminosity of the stars per unit surface equals that of the sun, the whole firmament would in fact glow with the intensity of the sun. An infinite luminosity would not be reached because the more distant stars would partly be hidden by the nearer ones.

In reality experience teaches us that the luminosity h_n is constantly decreasing with growing n, which is generally expressed in the statement that the star-density decreases the farther we travel from the sun. This is particularly demonstrated through the researches of Kapsteyn. This phenomenon may either be real, as assumed by most astronomers and by Mr. Charlier among them, or the explanation may be that the light from distant stars does not travel unchecked through space.

According to the last alternative, space is not entirely transparent. For this case two hypotheses have again been offered: first, the ether itself absorbs light; second, material bodies exist in space which disturb the ether. The first hypothesis lies too far outside our experience to be considered and would in fact demand structural changes in the ether due to radiating light (similar to chemical rearrangements) and capable of absorbing unlimited quantities of energy which is entirely incomprehensible.

The second hypothesis again assuming dark bodies in interstellar spaces agrees perfectly with our experience. The dark satellites that so frequently are introduced to explain the periodic displacement of the lines in the stellar spectra; the planets and moons in our solar system; the multitude of meteorites falling into our earth and whose parabolic orbits indicate their interstellar origin; the cosmic dust incessantly driven off from the sun by the light pressure—all exemplify such dark bodies. Generally one is satisfied by pointing out the existence of such light-absorbing matter. Another question, however, arises. How can these bodies remain at their low temperature when since immeasurable time they have been exposed to the radiation from the sun, unless, as assumed by most astronomers, their heat is dissipated in infinite space, which assumption on the other hand contradicts our original thesis that the density of matter in space, although small, possesses a definite value.

It has, however, always been held that the nebulas which are widely distributed over the heavens possess an exceedingly low temperature, because if the molecules in their outside layers were of higher temperature their thermal motion would expel them into space against the weak gravitational force of the extenuated nebula. In such gas formations small particles of cosmic dust are no doubt accumulated which absorb rays entering from outside space. The surrounding gas is thereby expanded. As Lane and Ritter have shown, this expansion is so great that a cooling is effected by such absorption of radiating light. The very probable assumption is here made that the nebulous gases, like the air of the earth, are mon- or di-atomic. The gas molecules that possess the highest velocity no doubt leave the nebula and roam about in space until attracted by denser bodies. They are then replaced by gas delivered from the interior of the nebula to the outer parts. Finally all the radiation from luminous, as well as dark, bodies is ultimately absorbed by the nebulas, which, however, are not heated thereby.

In order to fill this function the nebulas must occupy a relatively large surface in the heavens as compared with the luminous stars. According to Charlier's calculations all the visible stars taken together give a light 3000 times stronger than a star of the first magnitude. The sun on the other hand is one hundred thousand million times stronger than such a star or about 30 million times as strong as all visible stars together. Observed from earth the sun appears as a disc whose diameter occupies an arc of 1919 seconds. Consequently all the visible stars of the heavens together would form a disc of less diameter than 0.4 seconds. It is then assumed that the mean luminosity of the fixed stars per unit surface equals that of the sun. As the majority of the stars are white, while the sun is yellow, the estimate of 0.4 seconds is evidently considerably too high. Compare herewith a planetary nebula, No. 5 in Herschel's catalogue, near star B in the Great Bear, which occupies about 160 seconds and we see at once that this nebula alone covers more than 100,000 times as large a part of the firmament as all the visible stars together. Add hereto the enormously more rarified diffused nebulas with small power of absorbtion but occupying spaces several degrees square. Undoubtedly there also exists a number of feebly luminous nebulas that escape our power of observation.

It seems perfectly reasonable then to conclude that the nebulas are able to absorb the energy radiating from the stars. The nebulas also possess the ability to check the dust particles driven away from the sun by the light-pressure, so that these cold bodies may be considered as storage houses for the quantities of matter and energy that radiate from the hot suns.

While Von Olber's proof of the hypothesis that the density of the stars decreases as we travel from the sun does not seem quite convincing, Charlier on the other hand believes that he has found a much better argument for this theory accepted by the majority of astronomers. This argument was first propounded by Professor Seeliger in Munich (*Astr. Nachrichten*, 1895) later modified by Charlier and may be formulated as follows:

Suppose distributed throughout space gravitational masses M_0, M_1, M_2, etc., where numerous bodies, if far enough removed, may be treated as rigid systems; for instance constellations or Milky Ways outside our galaxy or systems of even higher order to which our sun and Milky Way do not belong and which therefore must be exceedingly remote. For simplicity's sake we assume with Charlier that the systems are globe-shaped. The potential V per unit mass of a body in our Milky Way is then:

$$V = A + M_0/r_0 + M_1/r_1 + M_2/r_2 + \dots\dots$$

A is the potential with reference to the nearest bodies belonging to the Milky Way. M_0/r_0, M_1/r_1, etc., are the potentials respectively with reference to outside systems.

Charlier presupposes that V cannot be infinite. Therefore the terms in the series M_0/r_0, M_1/r_1, etc., must decrease somewhat in a geometric progression, commencing with some certain term. The significance of this formula is easily understood. If we divide space as before, by circumscribing spheres with radii 1, 2, 3, etc., around the body selected as center, then beyond a certain radius the masses enclosed between consecutive pairs of spheres must diminish at a rate somewhat less than a geometric series would indicate. The star-density again would decrease very rapidly with growing distance from the galaxy. In this way the apparent result has been reached that the mass of the universe is finite.

It is not customary, however, to draw this conclusion. If we arrange the spheres in such a fashion that between any two consecutive spheres the mass contained is constant, it suffices to make the series converge if the associated distances r_0, r_1, r_2, etc., commencing with any certain term, increase in a geometric progression. As r_n becomes infinite only when n is infinite, it is possible to select any arbitrarily high value of n and nM; i. e., the quantity of matter in the universe exceeds any arbitrary great value. But in any case the mean density of stars in the universe equals zero (infinitely small).

This theory has been elaborated by Charlier to establish the possibility of an infinite universe. In spite hereof the solution is not satisfactory. Infinity of matter should then be of a lower order, so to speak, than infinity of space, so that the mean density of matter would be infinitely small (zero). Professor Seeliger correctly objects that a "space filled with infinitely rare matter can after all not be imagined."

One may now ask: why might not the potential V be infinite? The answer is, because then the velocity of a star arriving "from outside" would become infinite with reference to our point of observation, and we never observe any immeasurable velocities of the stars. Only in rare cases do these velocities exceed 100 kilometers per second. This would agree with the Charlier system if the traveling time of the stars could also be infinite. This, however, as we will see later, is impossible because such a system can only last for a finite period. But if we assume with the old philosophers an approximately uniform distribution of the stars throughout infinite space, no "outside," and consequently no danger of infinite, velocities exist.

In order to understand the peculiar development of this question so that the false conclusion drawn will become apparent, let us return to a simplification of Seeliger's reasoning already familiar to us. Imagine a globe-shaped conglomeration of stars of constant density throughout. A star at a certain distance from the center is attracted to it by a force proportional to the product of the density and the distance.

Although our Milky Way does not form such a globe, we must admit that somewhat similar conditions obtain if we assume its form to be that of a considerable oblate spheroid. If we now let the radius of our star-globe grow, the density remaining unaltered, the attraction on a star located on, say, half the radius increases in proportion to the radius. When the star-conglomeration grows beyond any limit chosen, the attraction on the star considered towards the center also grows beyond any limit mentioned. In addition the position of the center becomes undetermined, and so consequently does the attraction, which is unthinkable. Professor Seeliger also considers the case of the stars arranged inside an infinite cone of revolution and meets again with great difficulties.

In this connection Seeliger expresses himself as follows: "Entirely possible and reasonable assumptions lead to impossible and unreasonable consequences. Such results from an entirely general law seem hardly permissible and we are forced to admit that Newton's law applied to an infinitely extended universe leads to insurmountable difficulties and insolvable contradictions if the quantity of matter dispersed in the universe is considered unlimited."

Seeliger very consistently comes to the conclusion that Newton's law does not always hold as is evidenced by the following statement: "Newton's law is a purely empirical formula, the absolute exactness of which cannot be admitted without introducing a new hypothesis for which we have no foundation." But if we endeavor to formulate another law to substitute for Newton's when dealing with enormous distances, such a one can hardly be found which contains Newton's law for smaller distances and at the same time does not lead to the difficulties met with in the deductions of Seeliger. True, he offers a kind of absorption of gravity similar to that of light as a possible solution. But as we know of no matter with such powers the analogy is fictitious. We lose also by such considerations all firm ground for further discussion.

It is then easily understood why Seeliger's argument is often cited as disproving the infinity of the universe. But his reasoning is not conclusive. The supposed difficulty is that the attraction on a body surrounded by an infinite number of other bodies becomes indetermined according to Seeliger's method of calculation and consequently may assume any arbitrary value. But this only proves that such a method cannot be used, and how can we after all imagine an infinite globe containing stars surrounded by an infinite empty space? If a body is located in an infinite space where matter is approximately evenly distributed, the attraction due to this matter, apart from that due to the bodies in its vicinity, is equal in all directions as evidenced already by considerations of symmetry. These attractions consequently cancel and the body in question behaves exactly as under the influence of the nearest bodies or groups of bodies alone, with the more distant ones entirely removed or their attraction in some way absorbed.

No conclusive reason exists therefore why the universe should not be approximately uniformly interspersed with stars. On the contrary a system where the star-density rapidly decreases outwardly, like the system conceived by Charlier, or still more a finite system of celestial bodies, does not harmonize with our conceptions as soon as we take the second side of infinity, relating to time, into consideration.

If we legitimately discuss the conditions for an infinite quantity of matter in space we are also justified in considering the relation of matter to the endlessness of time. Peculiarly enough this problem given by Demokritos and Kant has aroused small interest on the part of astronomers, and yet we call the indestructibility of matter and energy our two fundamental laws of physics.

When we, with most astronomers, imagine large gaps in the firmament through which a ray of light may escape without encountering any material obstacle, however far it travels, so must matter driven away by the light-pressure as well as radiating energy disappear through these gaps forever to remain lost. The same fate is in store for those wandering stars, which like 1830 Groombridge and Arcturus, possess a velocity too high to be bound to our Milky Way. In the course of endless time such a system must lose not only its energy but also its matter. Neither can it have existed since immeasurable time.

Lord Kelvin says with reference to our Milky Way that if its mass is 10^9 times greater than that of the sun and its radius 3.09×10^{16} kilometers, so would its stars from original rest collapse in the course of about 17 million years into one lump. He also holds that the stars cannot have been luminous for more than 25 to 100 million years. Herewith should be compared the different estimates that allow life on earth an existence during about 1000 million years. The last estimate by Kelvin must in fact be considerably too low.

In any case the propounders of a finite universe or of the Charlier conception admit that the Milky Way must once have come into existence. We cannot assume that matter suddenly (or gradually) was born out of nothing, and the same is true about energy. Consequently the Milky Way must have originated from bodies that in some way, presumably through a catastrophe, were dispersed into a disc-shaped formation of splinters. We can hardly conceive of any mode of creation different from that in which the spiral nebulas are formed, that is, by the collision of two colossal stars that meet with enormous velocities and burst asunder. In fact Easton is of the opinion that our Milky Way possesses a spiral structure. The question is now whether or not such enormous stars exist. The mass of Arcturus has been calculated to be more than 50,000 times that of the sun. This is more than sufficient to give rise to the 6000 stars of the sixth magnitude that Seeliger takes into account. But it does not suffice for the 10^9 stars included in our galaxy by Kelvin and Charlier. It may reasonably be questioned whether the mean size of these stars equals that of the sun, and further the estimate of the mass of Arcturus is obviously only a lower limit. In any case such an explanation is not absolutely inconceivable.

Under any circumstances we must admit that the Milky Way is not a formation that has existed since eternity and that it owes its origin to the collision of stellar bodies journeying from other parts of the heavens. But if we assume the density of matter in space equal to zero, the probability for such an encounter becomes zero too; i. e., we cannot conceive of such a distribution of matter.

The most obvious argument, however, against a finite quantity of matter in space is the fact that the energy of the stellar bodies in the course of infinite time would long ago have been dissipated in empty space so that no luminous stars could further exist.

From the previous discussion I believe the conclusion may be drawn that no other world-conception is possible than the one already presented by the Greek nature philosophers Anaximander and Demokritos, who assumed matter to be distributed throughout the universe in a fashion approximately like that in our neighborhood.

Concerning the solution offered by Charlier in particular, according to which the Milky Ways combine into higher systems and these again into systems of still higher order, and so on, an enormous difficulty presents itself in explaining the origin of such systems. The same objection naturally holds in regard to the older theories of Swedenborg and Lambert. It is already very difficult to understand the formation of a system as large as the Milky Way. Incomparably more so becomes the explanation of systems greater beyond comparison.

With reference to the dissipation of energy through radiation and of matter through light-pressure from luminous stars, the Charlier world-conception meets with exactly the same difficulties as the assumption of a limited world in an unlimited space.

A finite world or a world where matter is infinitely rarefied cannot have existed in endless time and therefore does not harmonize with our knowledge of the qualities of energy and matter.

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